NONLINEAR HYSTERETIC TRUSS MODEL FOR DIAGONALLY REINFORCED CONCRETE COUPLING BEAMS

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ABSTRACT

Wall piers connected by diagonally reinforced concrete coupling beams are widely used as the lateral-force resisting system of tall buildings in seismic regions. A fundamental incongruity exists in current nonlinear modeling practice for such systems: walls are typically modeled in the initial uncracked state, whereas coupling beams are assigned a secant stiffness to the yield point. This paper presents the derivation of a nonlinear hysteretic truss model for diagonally reinforced concrete coupling beams that resolves this inconsistency and validates it against experimental data reported in the literature. The model explicitly couples flexural, shear, and axial deformations through truss action in a unified nonlinear hysteretic framework, offering a clear improvement over first-generation purely phenomenological models based on shear or moment springs. Unlike these models, the proposed model develops axial compression when restrained against lengthening, and accounts for the effects of this compression, allowing redistribution of the shear force between the framing wall piers. Its applicability is demonstrated through the nonlinear response history analysis of a fifteen-story coupled wall building.

RESEARCH SIGNIFICANCE

Several modeling alternatives are currently used in practice for diagonally reinforced coupling beams such as first-generation nonlinear lumped-plasticity bending moment and shear springs, and nonlinear shell elements. The springs are widely adopted because of their simplicity. A key limitation of these models is their inability to capture axial-shear–flexure interaction. Furthermore, the spring models assign an initial stiffness that represents a fraction of the uncracked stiffness of the beam, creating a fundamental incongruity in coupled wall models as the walls are assigned the uncracked stiffness. This paper presents the derivation of a simplified nonlinear hysteretic truss model that considers axial-shear-flexure interaction, is calibrated to match the initial uncracked stiffness of the beam and is suitable for use in modern performance-based seismic design practice. The model accounts for the increase in resistance in coupling beams due to compression resulting from axial restraint, as well as shear redistribution between wall piers.

SUPPLEMENTAL FILES

The nonlinear hysteretic truss model described in the paper sharing the name of this document is validated with six specimens of diagonally reinforced coupling beams (DRCB) found in the literature. The specimens include CB24F and CB33D by Naish et al,[1] D80-1.5 and D80-2.5 by Weber-Kamin et al,[2] CB1 by Ameen et al,[3] and CB1A by Poudel et al.[4] The truss model is used to compute the response of the DRCB of the seven-story coupled wall test of Santhakumar,[5] comparing the response of the same test when using a shear spring to represent the DRCB.

The application of the validated model is demonstrated in a nonlinear response history analysis of a building using commercial software (i.e., ETABS).[6]

The models for the DRCB, the coupled wall, and the building are found in the following link: https://github.com/SGodinez92/TrussModel_DRCB

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